Ask The Applications Engineer—39 Zero-Drift Operational Amplifiers

By Reza Moghimi

What Are Zero-Drift Amplifiers?

Zero-drift amplifiers dynamically correct their offset voltage and reshape their noise density. Two commonly used types—autozero amplifiers and choppers—achieve nanovolt-level offsets and extremely low offset drifts due to time and temperature. The amplifier's 1/f noise is also seen as a dc error, so it is removed as well. Zero-drift amplifiers provide many benefits to designers, as temperature drift and 1/f noise, always nuisances in the system, are otherwise very difficult to eliminate. In addition, zero-drift amplifiers have higher open-loop gain, power-supply rejection, and common-mode rejection as compared to standard amplifiers; and their overall output error is less than that obtained by a standard precision amplifier in the same configuration.

What Are Good Applications for Zero-Drift Amplifiers?

Zero-drift amplifiers are used in systems with an expected design life of greater than 10 years and in signal chains that use high closed-loop gains (>100) with low-frequency (<100 Hz), lowamplitude level signals. Examples can be found in precision weigh scales, medical instrumentation, precision metrology equipment, and infrared-, bridge-, and thermopile sensor interfaces.

How Does Auto-Zeroing Work?

Auto-zero amplifiers, such as the AD8538, AD8638, AD8551, and AD8571 families, usually correct for input offset in two clock phases. During Clock Phase A, switches labeled φ A are closed, while switches labeled φ B are open, as shown in Figure 1. The offset voltage of the nulling amplifier is measured and stored on capacitor C_{M1}.



Figure 1. Phase A of auto-zero amplifier: nulling phase.

During Clock Phase B, switches labeled φ B are closed, while switches labeled φ A are open, as shown in Figure 2. The offset voltage of the main amplifier is measured and stored on capacitor C_{M2} , while the stored voltage on capacitor C_{M1} adjusts for the offset of the nulling amplifier. The overall offset is then applied to the main amplifier while processing the input signal.



Figure 2. Phase B of auto-zero amplifier: auto-zero phase.

The sample-and-hold function turns auto-zero amplifiers into sampled-data systems, making them prone to aliasing and fold-back effects. At low frequencies, noise changes slowly, so the subtraction of two consecutive noise samples results in true cancellation. At higher frequencies this correlation diminishes, with subtraction errors causing wideband components to fold back into the baseband. Thus, auto-zero amplifiers have more in-band noise than standard op amps. To reduce low-frequency noise, the sampling frequency has to be increased, but this introduces additional charge injection. The signal path includes only the main amplifier, so relatively large unity-gain bandwidth can be obtained.



Figure 3. Chopping scheme used in the ADA4051.

Figure 3 shows the block diagram design of the ADA4051 chopper amplifier, which uses a local autocorrection feedback (ACFB) loop. The main signal path includes input chopping network CHOP1, transconductance amplifier Gm1, output chopping network CHOP2, and transconductance amplifier Gm2. CHOP1 and CHOP2 modulate the initial offset and 1/f noise from Gm1 up to the chopping frequency. Transconductance amplifier Gm3 senses the modulated ripple at the output of CHOP2. Chopping network CHOP3 demodulates the ripple back to dc. All three chopping networks switch at 40 kHz. Finally, transconductance amplifier Gm4 nulls the dc component at the output of Gm1—which would otherwise appear as ripple in the overall output. The switched capacitor notch filter (SCNF) selectively suppresses the undesired offset-related ripple without disturbing the desired input signal from the overall output. It is synchronized with the chopping clock to perfectly filter out the modulated components.

Can the Two Techniques Be Combined?

This is exactly what is done in a new series of amplifiers from Analog Devices. The AD8628 zero-drift amplifier, shown in Figure 4, uses both auto-zeroing and chopping to reduce the energy at the chopping frequency, while keeping the noise very low at lower frequencies. This combined technique allows wider bandwidth than was possible with conventional zero-drift amplifiers.



Figure 4. The AD8628 combines auto-zeroing with chopping to achieve wider bandwidth.

What Applications Issues Are Encountered When Using Zero-Drift Amplifiers?

Zero-drift amplifiers are composite amplifiers that use digital circuitry to dynamically correct for analog offset errors. The charge injection, clock feedthrough, intermodulation distortion, and increased overload recovery time that result from the digital switching action can cause problems within poorly designed analog circuits. The magnitude of the clock feedthrough increases with an increase in closed-loop gain or source resistance; adding a filter at the output or using a lower resistance on the noninverting input will reduce the effect. Also, the output ripple of a zero-drift amplifier increases as the input frequency gets closer to the chopping frequency.

What Happens to Signals at Frequencies Higher Than That of the Internal Clock?

Signals with frequencies greater than the auto-zero frequency can be amplified. The speed of an auto-zeroed amplifier depends on the gain-bandwidth product, which is dependent on the main amplifier, not the nulling amplifier; the auto-zero frequency gives an indication of when switching artifacts will start to occur.

What Are Some Differences Between Auto-Zeroing and Chopping?

Auto-zeroing uses sampling to correct offset, while chopping uses modulation and demodulation. Sampling causes noise to fold back into baseband, so auto-zero amplifiers have more in-band noise. To suppress noise, more current is used, so the devices typically dissipate more power. Choppers have low-frequency noise consistent with their flat-band noise but produce a large amount of energy at the chopping frequency and its harmonics. Output filtering may be required, so these amplifiers are most suitable in low-frequency applications. Typical noise characteristics of auto-zero and chopping techniques are shown in Figure 5.



Figure 5. Typical noise of various amplifier topologies vs. frequency.

When Should I Use Auto-Zero Amplifiers? When Should I Use Choppers? Choppers are a good choice for low-power, low-frequency applications (<100 Hz), while auto-zero amplifiers are better for wideband applications. The AD8628, which combines auto-zero and chopping techniques, is ideal for applications that require low noise, no switching glitch, and wide bandwidth. Table 1 shows some of the design trade-offs.

Table 1.								
Auto-Zero	Chopper Stabilized	Chopper Stabilized + Auto-Zero						
Very low offset, TCV _{OS}	Very low offset, TCV _{OS}	Very low offset, TCV _{OS}						
Sample-and-hold	Modulation/ demodulation	Sample-and- hold, modulation/ demodulation						
Higher low- frequency noise due to aliasing	Similar noise to flat band (no aliasing)	Combined noise shaped over frequency						
Higher power consumption	Lower power consumption	Higher power consumption						
Wide bandwidth	Narrow bandwidth	Widest bandwidth						
Lowest ripple	Higher ripple	Lower ripple level than chopping						
Little energy at auto-zero frequency	Lots of energy at chopping frequency	Little energy at auto-zero frequency						

What Are Some of ADI's Popular Zero-Drift Amplifiers?

Table 2 shows a sample of zero-drift amplifiers offered by ADI.

References

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Author

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Devices in 1990. At ADI, he has served in test-, product-, and project-engineering assignments. He has written many articles and design ideas—and has given presentations at technical seminars. His hobbies include travel, music, and soccer.

Part Number		Suj Vol	pply tage	Rail- to-Rail		BW (a) A _{CL} Slew		TCV _{os}		PSRR	Avol	Noise	I _S / Amp			
Single	Dual	Quad	Min	Max	In	Out	Min (MHz)	Rate (V/μs)	Max (µV)	Typ (µV/°C)	Min (dB)	Min (dB)	Min (dB)	@ 1 kHz (nV/√Hz)	Max (mA)	Topology
AD8628	AD8629	AD8630	2.7	5.5	•	•	2.5	1	5	0.002	120	115	125	22	1.1	AZ, C
AD8538	AD8539		2.7	5.5	•	•	0.43	0.4	13	0.03	115	105	115	50	0.18	AZ
AD8638	AD8639		4.5	16		•	1.35	2.5	9	0.01	118	127	120	60	1.3	AZ
AD8551	AD8552	AD8554	2.7	5.5	•	•	1.5	0.4	5	0.005	120	120	125	42	0.975	AZ
AD8571	AD8572	AD8574	2.7	5.5	•	•	1.5	0.4	5	0.005	120	120	125	51	0.975	AZ
ADA4051-1	ADA4051-2	ĺ	1.8	5.5	•	•	0.115	0.04	15	0.02	105	110	106	95	0.017	С

Table 2.